Shellshocked: A Comprehensive Review of PFAS in Shellfish

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Background

- **Per- and polyfluoroalkyl substances (PFAS)** are emerging pollutants that threaten human health.
- Need to understand **the role of shellfish in the transport of PFAS** and as source of **dietary exposure for consumers**.

Human Exposure to PFAS

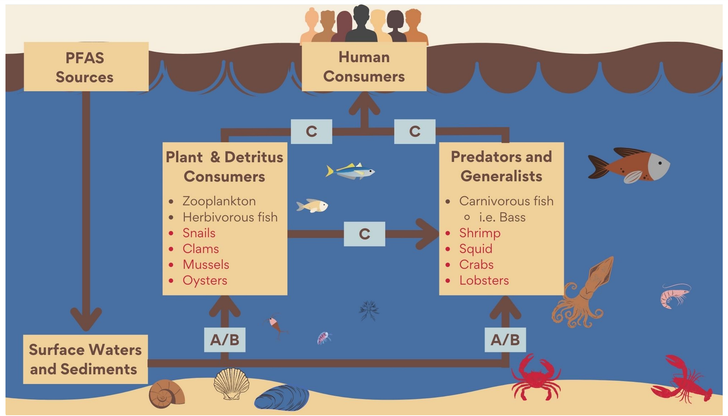


Figure 1: Conceptual model for PFAS exposure to humans via the consumption of shellfish. Boxes represent compartments where PFAS may accumulate. Arrows represent processes like bioaccumulation (A), bioconcentration (B), and biomagnification (C). Red text denotes taxa that meet the definition of shellfish in this review.

Objective

Review occurrence, bioaccumulation, and risk of PFAS in shellfish

Methods

Paper Search Criteria

- Peer-reviewed studies
- Analyze raw, soft tissues
- Report concentrations by individual shellfish species

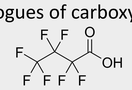
Data

- 24 studies
- 60 + species
- Six continents
- HPLC (67% studies) and LCMS (33% studies)
- Published 2005-2021

Compounds of Interest:

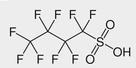
- **Perfluoroalkyl Carboxylic Acids (PFCA)** – Organofluorine analogues of carboxylic acids

Ex. Perfluorobutanoic acid (PFCA C4)



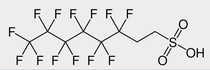
- **Perfluoroalkyl Sulfonic Acids (PFSA)** – Organofluorine analogues of sulfonic acids

Ex. Perfluorobutane sulfonic acid (PFSA C4)



- **PFAS Precursors** – Fluorochemicals that transform into other PFAS

Ex. Fluorotelomer Sulfonic Acid 6:2 (6:2 FTS)



PFAS Nomenclature Examples:

Acronym	Compound Name	# Carbon in Backbone
PFBA	Perfluorobutanoic acid	4
PFBS	Perfluoropentane Sulfonic acid	4

Results

Occurrence by Class and Habitat Type

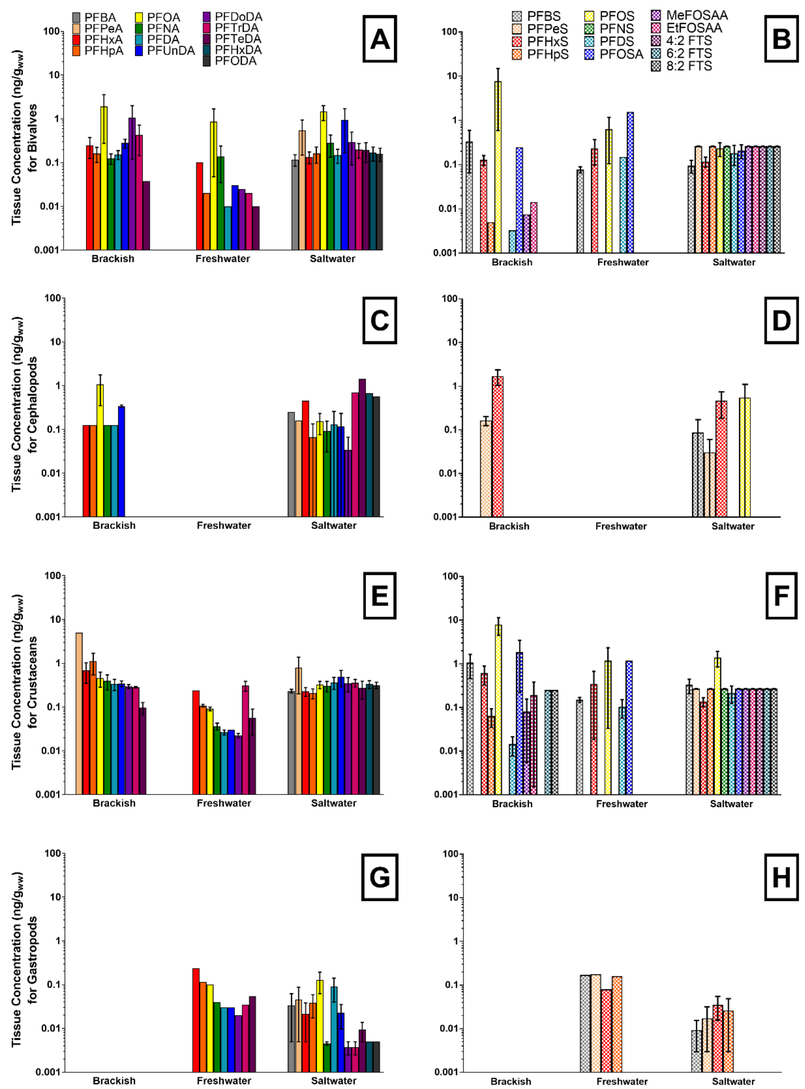


Figure 1: Concentrations of perfluoroalkyl carboxylic acids (PFCAs) for bivalves (A), cephalopods (C), crustaceans (E) and gastropods (G) along with perfluoroalkyl sulfonic acids (PFSAs) bivalves (B), cephalopods (D), crustaceans (F) and gastropods (H). All concentrations are reported as mean ± standard error of the mean (SEM) of averages reported in occurrence studies

→ **Finding:** PFAS concentrations vary across different habitat types and major taxonomic groups within . Across all habitats, PFOS and perfluorooctane sulfonamide (PFOSA) had the highest concentrations of any analyte.

Bioaccumulation Factors

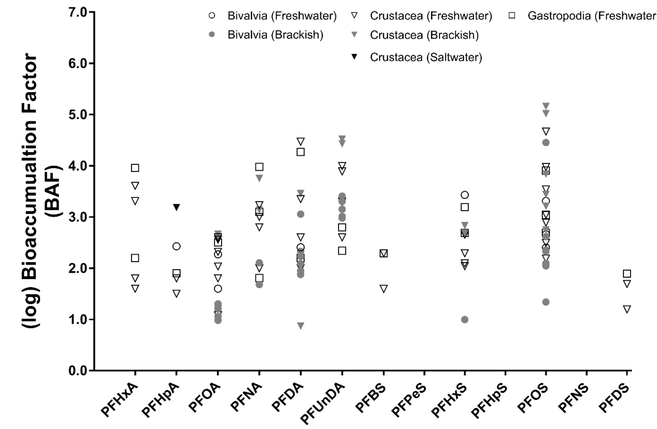


Figure 2: Log transformed bioaccumulation factors (BAFs) for PFAS identified in this review. Y-axis represents log values for BAF while x-axis is studied PFCA and PFSA ordered by chain length.

→ **Finding:** There is scant data for drawing conclusions about patterns in bioaccumulation.

Exposure Ratio for Bivalves

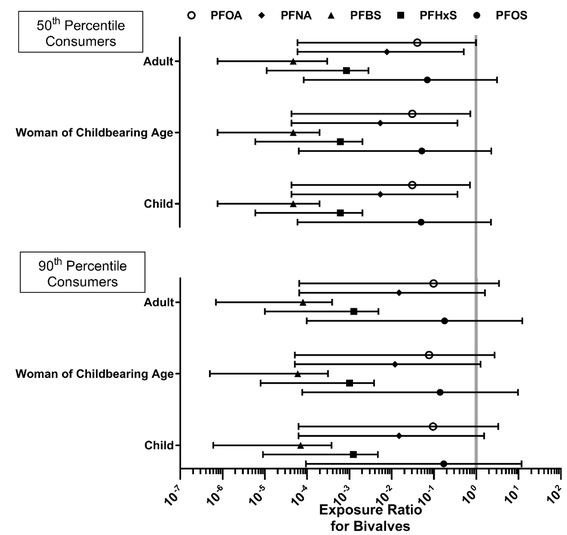


Figure 3: Exposure ratios for various consumers of bivalves based on concentrations reported from reviewed studies. The grey line at "1" indicates a consumed dosage equal to the threshold dose for risk described by either the Agency for Toxic Substances and Disease Registry (ATSDR) or U.S. EPA for respective PFAS. Each symbol represents the exposure ratio based on a calculation using the median observed PFAS concentration, with the bars extending to show the minimum (left bar) and maximum (right bar) observed PFAS concentrations.

→ **Finding:** Among all average and high-end consumers, the highest reported concentrations of PFOS in bivalves resulted in excess exposure concentrations.

Summary

- **No clear trends in occurrence** by habitat, chain length, or taxonomic group
- **No clear trends in BAF** by habitat, chain length, or taxonomic group
- **Highest reported concentrations of some analytes cross excess exposure threshold**
- **A diverse range of methodologies and occurrences**
- **Need for standardization of shellfish sampling/analytical methodologies**
- **Need for more data** on occurrence and toxicity of PFAS

Funding and References

National Institute of Environmental Health Sciences (NIEHS): R21 ES032187 (S1)
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Occurrence and Risks of Per- and Polyfluoroalkyl Substances in Shellfish (Giffard, et al. 2023)

For a complete list of references, email: Nathan.Gerard.Giffard@dartmouth.edu